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United States Department of Agriculture  
Natural Resources Conservation Service  
Bismarck, North Dakota

# Switchgrass Biomass Trials in North Dakota, South Dakota, and Minnesota



*Helping People Help the Land*



The background of the entire page is a close-up photograph of numerous yellow, oval-shaped switchgrass seeds. The seeds are densely packed and have a smooth, slightly glossy texture. A white rectangular box is positioned at the top center of the page, partially overlapping the seed background.

## Who We Are

*Plants are an important tool for conservation. The Bismarck Plant Materials Center (PMC) is part of the United States Department of Agriculture, Natural Resources Conservation Service (USDA, NRCS). It is one of a network of 27 centers nationwide dedicated to providing vegetative solutions to conservation problems. The Plant Materials program has been providing conservation plant materials and technology since 1934.*

## Contact Us

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*In this photo:  
Switchgrass has  
approximately  
390,000 small, smooth  
seeds per pound.*

## Acknowledgements

*Cooperators and partners in the warm-season grass evaluation trials together with the USDA, NRCS Plant Materials Center at Bismarck, North Dakota, have included: the U.S. Department of Interior, Fish and Wildlife Service (J. Clark Salyer National Wildlife Refuge near Upham, North Dakota; the Wetland Management District at Fergus Falls, Minnesota; and the Karl E. Mundt National Wildlife Refuge near Pickstown, South Dakota); the South Dakota Department of Agriculture Forestry Division; the South Dakota Department of Game, Fish, and Parks; the Minnesota Department of Natural Resources, Division of Forestry; the U.S. Army Corps of Engineers; the USDA, NRCS field and area offices and Soil and Water Conservation District offices located at Bottineau, North Dakota; Fergus Falls, Minnesota; Lake Andes, South Dakota; Onida, South Dakota; Rochester, Minnesota, and Pierre, South Dakota; the Southeastern Minnesota Association of Soil and Water Conservation Districts; the Hiawatha Valley Resource Conservation and Development Area (Minnesota); and the North Central Resource Conservation and Development Office (South Dakota).*



# Switchgrass Biomass Trials in North Dakota, South Dakota, and Minnesota

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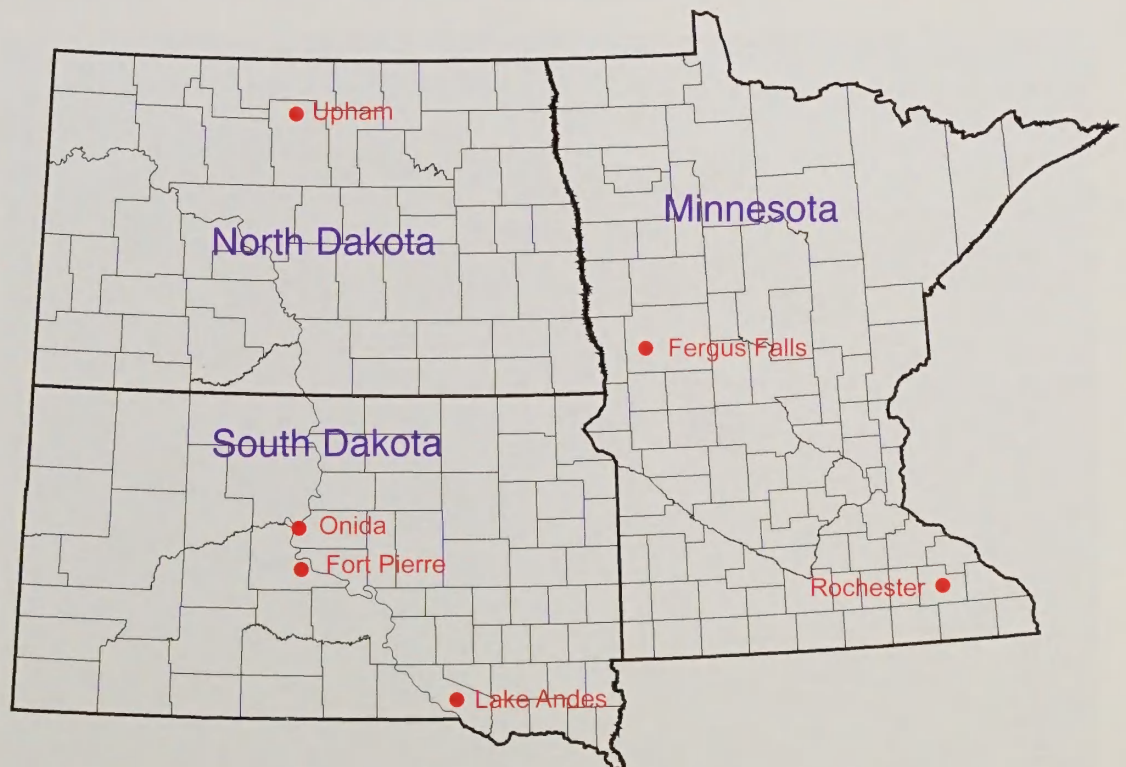
*Dwight Tober, Plant Materials Specialist; Wayne Duckwitz, PMC Manager; Nancy Jensen, Agronomist;  
and Mike Knudson, Assistant Manager; USDA, NRCS, Bismarck, North Dakota*

Switchgrass (*Panicum virgatum* L.) is a native, deep-rooted, warm-season grass with stout rhizomes and heavy biomass growth during late spring and early summer. The species occurs naturally in every State in the continental United States, except for Oregon, Washington, and California (USDA, NRCS 2006b). It is an abundant seed producer. Clean seed yields in excess of 700 pounds per acre have been documented at the USDA, NRCS Plant Materials Center (PMC) at Bismarck, North Dakota. Switchgrass tolerates a wide range of soil conditions and is widely acclaimed as a conservation plant for erosion control, pasture and hayland planting, wildlife habitat, and native prairie restoration. Interest in switchgrass as a renewable biofuel resource has grown in recent years.

Dry matter biomass yields and other information were compiled from 1982 to 1992 at six sites in North Dakota, South Dakota, and Minnesota. The effects of seed origin (parentage) on plant performance was apparent. Ten seed sources/varieties of switchgrass were evaluated. Southern seed sources generally had heavier biomass production. Plant density (stand index) was generally greater for northern origin seed sources. Northern seed sources moved more than 200 miles southward from their origin generally performed poorly, and biomass was significantly less than local or more southern origin sources. There were less days to seed maturity (phenology) for the more northern origin seed sources compared to the more southern origin seed sources.

## Trial Sites

The trial sites were studied in cooperation with numerous partners (see Acknowledgements). They were located near Upham, North Dakota; Fergus Falls, Minnesota; Rochester, Minnesota; Lake Andes, South Dakota; Onida, South Dakota; and Fort Pierre, South Dakota. Soils and precipitation information are included with the tables. Growing seasons at the six locations varied from an average of 110 days at





Upham, North Dakota, to an average of 150 days at Rochester, Minnesota. Average annual precipitation ranged from 15 to 30 inches. Seven to nine different species of warm-season grasses were evaluated at each site. Each species included two or more varieties or seed sources. Switchgrass is the only species presented in this report.

*The studies were completed cooperatively with numerous partners.*



## Methods and Materials

The experimental design was a randomized complete block with three replications for data collection. An evaluation array was seeded for demonstration purposes. Plot size varied from 12 to 15 feet in width, and from 60 to 100 feet in length. A clean, firm seedbed was prepared by disking, harrowing, and roller packing. The plots were seeded with a native grass drill. Herbicides were used for weed control. Residue biomass was removed each spring either by mowing and raking, or burning. No fertilizer was applied.



*A clean, firm seedbed was prepared at all six sites including this location at Fergus Falls, Minnesota.*

Data collection at all six locations included stand ratings, plant height, weed contamination, stand index density, phenology, and annual biomass harvest. Only biomass harvest, stand density, and phenology are presented and discussed.

Stand index density was determined by estimating the number of plants in a 9-inch by 16-inch quadrat. Ten quadrats were



systematically counted near the center of each plot. A density index rating was developed. Values ranging from 0 to 40 plants per square foot were used to estimate density for each subsample.

Oven-dried biomass production was documented at all sites beginning the second year following establishment. Biomass production was determined by clipping a 2 foot by 10 foot subplot in each plot with a forage harvester. Sampling dates were as close as possible to the end of the growing season (first killing frost). The sample plots were systematically located within each plot across the treatment and clipped to a stubble height of approximately 2 inches. After weighing the large samples, small (100 gram) grab-samples were also weighed, oven-dried at 60 degrees C for 48 hours, and reweighed to determine moisture content. Percent dry matter weight of the large sample was then used to determine average annual biomass production in pounds per acre.

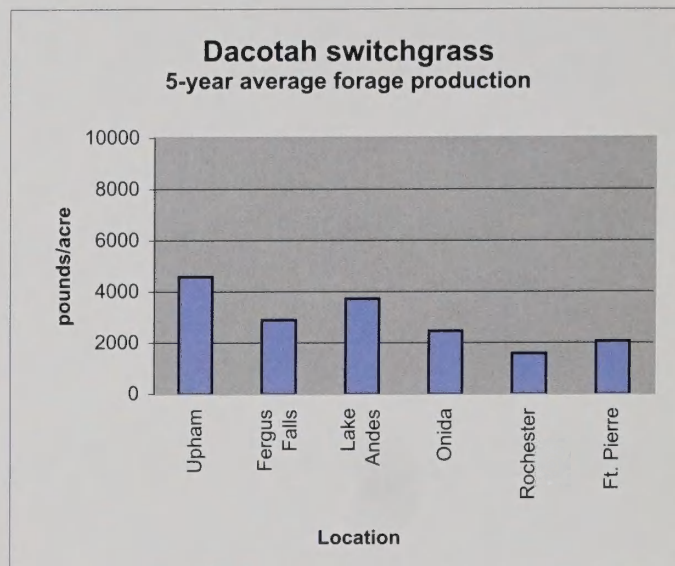




## Variety/Seed Source Origins

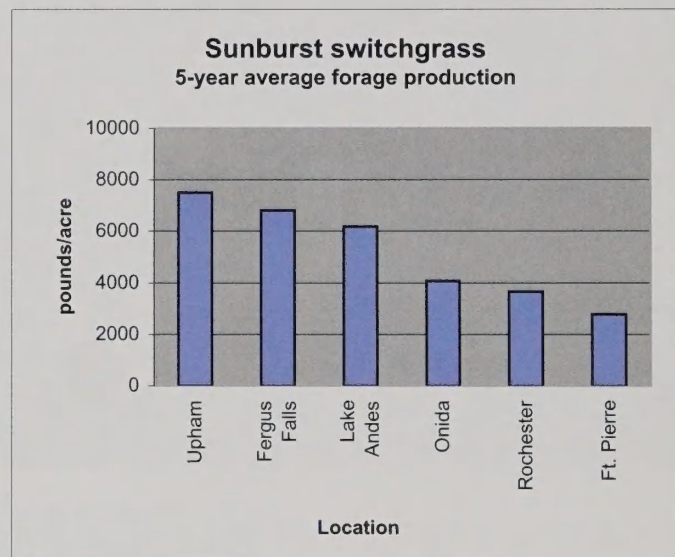
### Dacotah

The original plants (NDG-965-98) were collected from a native stand near Breien, Morton County, in south central North Dakota. Plants were selected for leafiness, plant vigor, seed yield, winter hardiness, and uniform color. Dacotah flowers 27 days earlier than Forestburg, and 45-50 days earlier than Blackwell, Summer, Cave-in-Rock, Pathfinder, and Nebraska 28. Its mature height is shorter and growth is less coarse compared to more southern varieties. It has increased drought tolerance for this species. The chromosome number is  $2n=4x=36$ . Dacotah was released by the USDA Natural Resources Conservation Service and Agricultural Research Service.



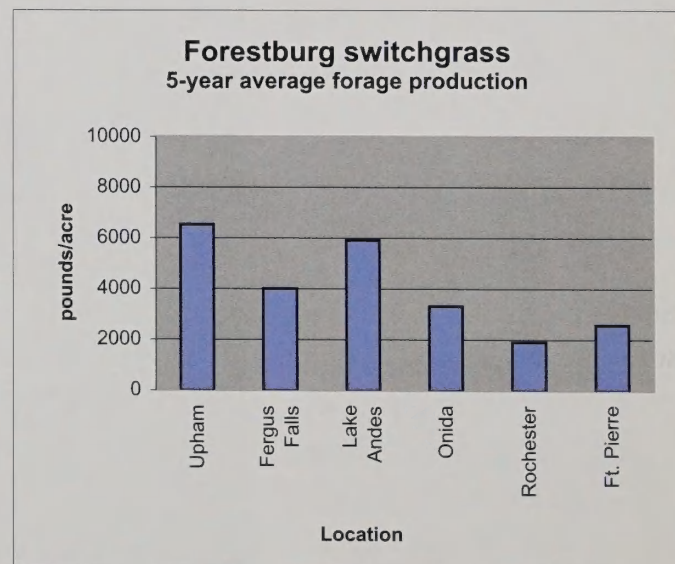
### Sunburst

The original seed was collected near Yankton in southeastern South Dakota. Selections from original seeded plants were chosen for large seed size, higher seedling survival and better stand establishment. It is a medium maturity selection with good forage yields. Sunburst has a broad area of adaptation and has performed well in trials along the Canadian border in North Dakota.



### Forestburg

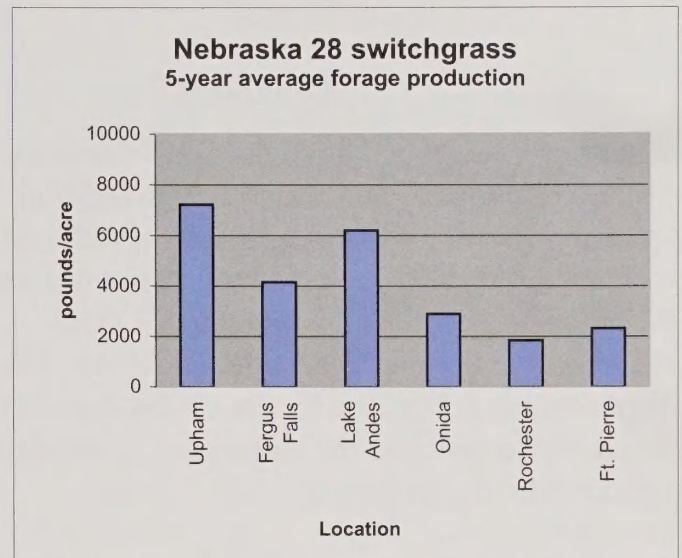
It is a composite (SD-149) of four accessions collected from native stands near Forestburg, Sanborn County, in east central South Dakota. Early maturity, persistence, forage yield and quality, winter hardiness, and seed production were key selection criteria. Forage production at northern latitudes exceeds production of Dacotah and is similar to Nebraska 28 and Sunburst. The chromosome number is  $2n=6x=36$ . Forestburg was a joint USDA Natural Resources Conservation Service and Agricultural Research Service release.





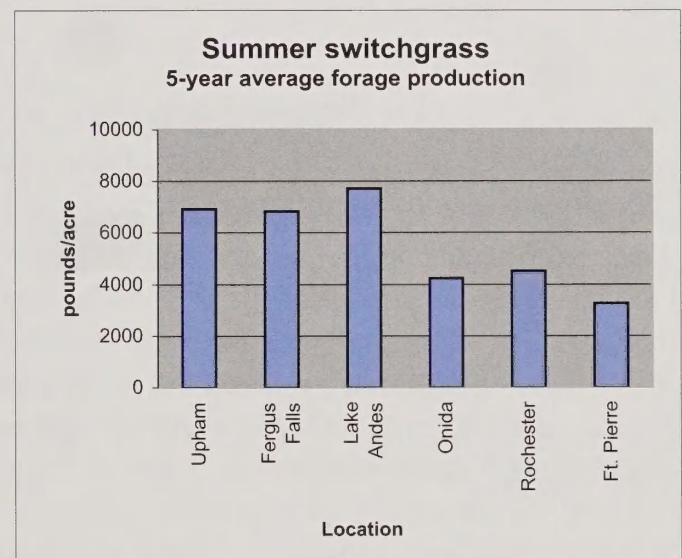
### **Nebraska 28**

It was collected from a native switchgrass stand in Holt County, in northeast Nebraska. This is a relatively early maturing strain of switchgrass representative of the Nebraska sandhill types. There is considerable variation in plant type. The average plants are semi-decumbent, with fine stems of moderate height, bluish green, and leafy. It is susceptible to rust in areas with longer growing seasons. Nebraska 28 was released by the Nebraska Agricultural Experiment Station, the USDA Natural Resources Conservation Service, and the Agricultural Research Service.



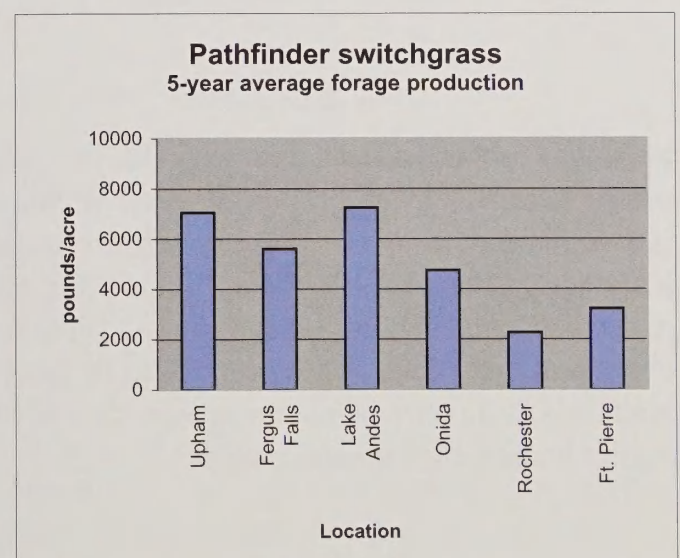
### **Summer**

It was a native collection made near Nebraska City, Otoe County, in southeast Nebraska. Mass selection was made for earliness, leafiness, and rust resistance. It has an erect, upright growth habit with a high degree of uniformity, and abundant, somewhat coarse leaves. Forage and seed yields are abundant. Seed size is smaller than other switchgrass varieties. Summer was released by the South Dakota Agricultural Experiment Station.



### **Pathfinder**

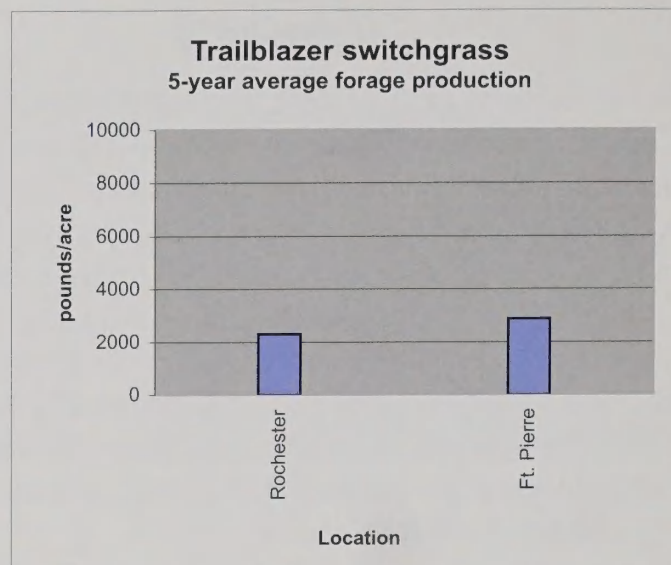
It originated from domestic collections from Nebraska and Kansas. It is winter hardy, vigorous, leafy, late maturing, and rust resistant in region of adaptation. Stand establishment and forage production is good. Seed production is best in the eastern third of Nebraska, south of the Platte River. Pathfinder was released by the Nebraska Agricultural Experiment Station, the USDA Natural Resources Conservation Service, and the Agricultural Research Service.





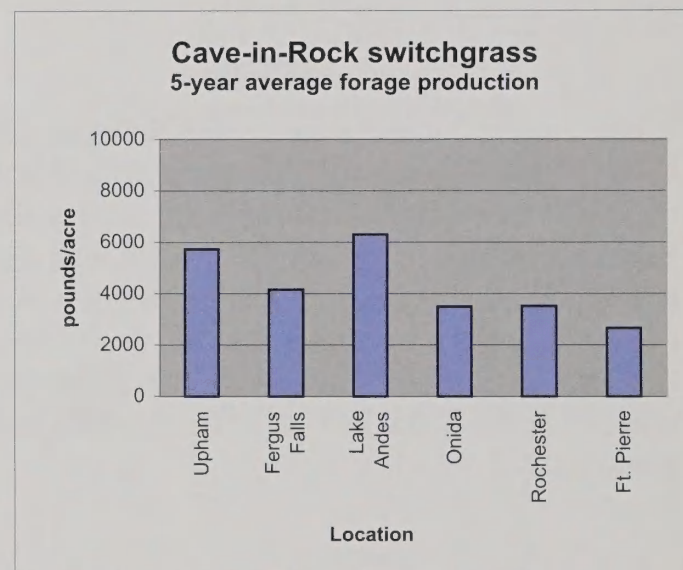
### **Trailblazer**

It was collected from grasslands in Nebraska and Kansas. Trailblazer is similar to Pathfinder in maturity, appearance, and area of adaptation. It was selected for improved forage quality and the in vitro dry matter digestibility is greater than Pathfinder. The chromosome number is hexaploid ( $2n=6x=54$ ). Trailblazer was released by the USDA Agricultural Research Service and the University of Nebraska Department of Agronomy.



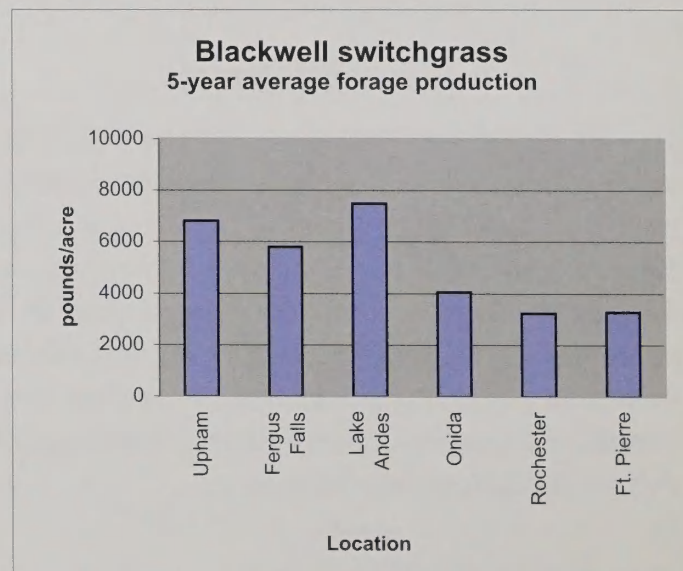
### **Cave-in-Rock**

It was selected from a native stand near Cave-in-Rock in southern Illinois. It was selected for seedling vigor, disease resistance, higher seed yields, and resistance to lodging. This is a lowland type of switchgrass. It is tolerant to flooding, but will also withstand droughty soils. Cave-in-Rock was released by the USDA Natural Resources Conservation Service and the Missouri Agricultural Experiment Station.



### **Blackwell**

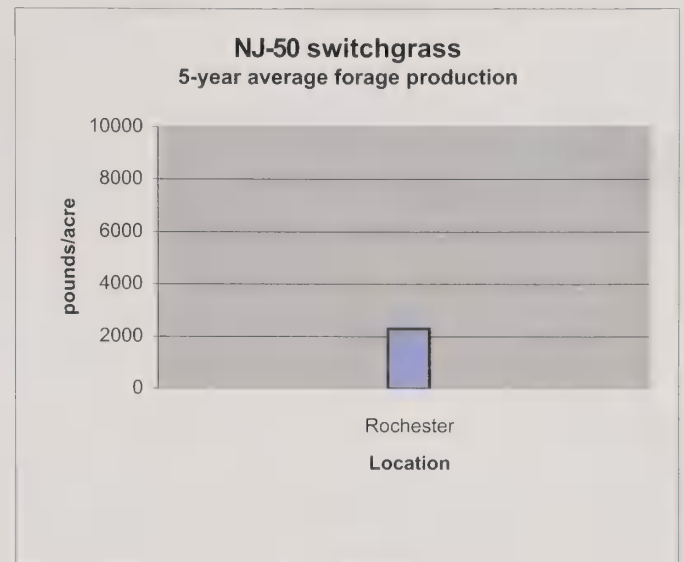
Seed was harvested from a single plant in a native prairie near Blackwell, in north central Oklahoma. This is an upland type switchgrass of medium height that is leafy and has large stems. Total forage yield, disease resistance, and seedling vigor is good. It has a wide area of adaptation. Blackwell was released by the USDA Natural Resources Conservation Service and the Kansas Agricultural Experiment Station.





### **NJ-50**

A single clone was collected vegetatively near Carthage, North Carolina. It is leafy and has better than average spread, high nutrient value, and early spring recovery. Seed production is fair. This seed source is not an official release.



## **Results and Discussion**

Biomass yields at all six locations were heavily dependent on seasonal precipitation patterns. Similar to what Boe (2005) reported for trials in South Dakota, biomass production was strongly associated with total April and May precipitation. Seed origin was also critical in overall performance. Previous studies at the Bismarck PMC have shown that generally, warm-season grass species can be moved about 300 miles north or 200 miles south of their original collection location. East and west movement is affected by moisture and elevation (USDA, NRCS 2006). Dacotah ranked lowest in 5-year average biomass yield at all six sites. Dacotah was the northernmost origin of switchgrass in the trials and is noted for its short stature and early maturity. Varieties producing the most biomass varied across the plot locations, but generally, the more southern origin varieties produced the most biomass. No winter injury was reported for any switchgrass variety at any of the test sites. Previous studies have reported winter injury for some warm-season grass species planted in North Dakota (Jacobson et al 1986). Berdahl et al. (2005) reported winter injury on southern switchgrass varieties planted in North Dakota. Sunburst and Summer ranked near the top in biomass production at 5 of the 6 sites. Berdahl et al. (2005) also reported that Sunburst was ranked first or second in biomass yield at three sites in North Dakota.

Stand index densities were rated at all six sites. Generally, the more northern origin seed sources, Dacotah and Forestburg, had the highest ratings. Cave-in-Rock consistently rated low in stand index density at all sites. The effects of soil differences on stand density were not apparent.

Phenology was variable across sites with annual rainfall and temperatures affecting plant maturity. Varieties having the earliest and the latest maturities were very similar at all six sites. Dacotah had the earliest maturity at all sites. It had mature seed in early August at the Upham, North Dakota, site and had mature seed in early September at the other five sites. Generally, when seed was ripe for Dacotah, the varieties of Sunburst, Forestburg, and Nebraska 28 were at 50 percent anthesis to first seed ripe. The remaining six southern or eastern varieties were similar in phenology, although they were greatly affected by growing season precipitation. Generally, the first emergence of inflorescence or first anthesis stage was near the end of the growing season.



## Upham, North Dakota

Average annual precipitation for the 5 years of biomass harvest was near normal. The lowest biomass production was in 1987 when precipitation was 1.23 inches below normal. Average biomass yields were generally excellent on the fertile silty clay loam soils. Sunburst, Nebraska 28, Pathfinder, and Summer all produced an average of 7,000 pounds per acre or greater. Dacotah (29), Forestburg (27), and Pathfinder (27) had the highest stand index ratings. Dacotah had mature seed in early August. Sunburst, Forestburg, and Nebraska 28 were at the first seed ripe stage. The first killing frost at this site is often as early as late August.

### Upham, North Dakota (MLRA 55A, north central ND)

**Average Annual Precipitation:** 16.08 inches

**Soils:** Great Bend silty clay loam

Variety	(pounds/acre) Biomass <sup>1</sup>							Stand Index <sup>2</sup>	Phenology <sup>3</sup>
	1983	1984	1985	1986	1987	Avg	Rank	1982-1984*	Early August
Precip. deviation	(0.98)	(0.9)	(1.63)	(-0.09)	(-1.23)				
<b>Dacotah</b>	6498 <i>d</i>	5164 <i>b</i>	4534 <i>b</i>	4488 <i>b</i>	2177 <i>b</i>	4572	8	29	8
<b>Sunburst</b>	9639 <i>a</i>	7635 <i>a</i>	7581 <i>a</i>	7791 <i>ab</i>	4848 <i>a</i>	7499	1	18	6
<b>Forestburg</b>	8037 <i>bc</i>	6356 <i>ab</i>	6475 <i>ab</i>	6950 <i>ab</i>	4825 <i>a</i>	6529	6	27	6
<b>Nebraska 28</b>	6859 <i>cd</i>	7428 <i>ab</i>	7167 <i>ab</i>	8925 <i>a</i>	5703 <i>a</i>	7216	2	12	6
<b>Summer</b>	9426 <i>ab</i>	5410 <i>ab</i>	6717 <i>ab</i>	7226 <i>ab</i>	5773 <i>a</i>	6910	4	21	1
<b>Pathfinder</b>	8782 <i>ab</i>	6867 <i>ab</i>	6940 <i>ab</i>	6566 <i>ab</i>	6058 <i>a</i>	7043	3	27	3
<b>Cave-in-Rock</b>	6900 <i>cd</i>	5298 <i>ab</i>	5857 <i>ab</i>	5437 <i>b</i>	5023 <i>a</i>	5703	7	19	3
<b>Blackwell</b>	9335 <i>ab</i>	5911 <i>ab</i>	7493 <i>ab</i>	6061 <i>ab</i>	5221 <i>a</i>	6804	5	20	3

**Statistical Analyses:** Duncan's New Multiple Range Test, means with same letter are not significantly different (P=.05)

<sup>1</sup>**Biomass:** flail-type forage harvester, 2' x 10' strip in each plot clipped to a 2 inch stubble height

<sup>2</sup>**Stand Index:** Estimate of plant density in 10 (1.0 sq ft) quadrats per plot. Full frame=40

<sup>3</sup>**Phenology (1984):** 1= vegetative; 2=jointing; 3=first emergence of inflorescence; 4=first anthesis, 10 culms or more; 5=50% anthesis; 6 = first seed ripe; 7 = 50% seed ripe; 8 = seed mature; 9 = complete dormancy.

\* Data is an average from these years





## Fergus Falls, Minnesota

The soils on this site are a well drained loam complex formed in calcareous glacial till. Two years of well below normal precipitation in 1983 (-3.96) and 1987 (-7.2) greatly reduced the 5-year average biomass yields. Summer and Sunburst had the highest yields at near 7,000 pounds per acre. Stand index ratings were highest for Forestburg (27) and Dacotah (26). The phenology ratings were very similar to those at the Upham site.

### Fergus Falls, Minnesota (MLRA 102A, west central MN)

**Average Annual Precipitation:** 23.52 inches

**Soils:** Barnes and Langhei loam

Variety	(pounds/acre) Biomass <sup>1</sup>							Stand Index <sup>2</sup>	Phenology <sup>3</sup>
	1983	1984	1985	1986	1987	Avg	Rank	1982-1984*	Early September
Precip. deviation	(-3.96)	(1.54)	(.85)	(6.23)	(-7.2)				
<b>Dacotah</b>	3365 <i>b</i>	3798 <i>b</i>	2277 <i>c</i>	3423 <i>b</i>	1551 <i>b</i>	2883	8	26	8
<b>Sunburst</b>	6240 <i>ab</i>	9113 <i>a</i>	7016 <i>ab</i>	6898 <i>a</i>	4703 <i>a</i>	6794	2	20	5
<b>Forestburg</b>	5909 <i>ab</i>	4292 <i>b</i>	3901 <i>bc</i>	3605 <i>b</i>	2279 <i>b</i>	3997	7	27	5
<b>Nebraska 28</b>	3412 <i>b</i>	6104 <i>ab</i>	3635 <i>bc</i>	4568 <i>ab</i>	2994 <i>ab</i>	4143	6	16	5
<b>Summer</b>	9011 <i>a</i>	7286 <i>ab</i>	7564 <i>a</i>	6218 <i>ab</i>	4024 <i>a</i>	6821	1	22	4
<b>Pathfinder</b>	9551 <i>a</i>	7078 <i>ab</i>	4827 <i>abc</i>	4336 <i>ab</i>	2226 <i>b</i>	5603	4	18	3
<b>Cave-in-Rock</b>	4910 <i>b</i>	5916 <i>ab</i>	4579 <i>abc</i>	3474 <i>b</i>	1876 <i>b</i>	4151	5	18	3
<b>Blackwell</b>	7152 <i>ab</i>	8613 <i>a</i>	5066 <i>abc</i>	5229 <i>ab</i>	2964 <i>ab</i>	5805	3	23	3

**Statistical Analyses:** Duncan's New Multiple Range Test, means with same letter are not significantly different (P=.05)

<sup>1</sup>**Biomass:** flail-type forage harvester, 2' x 10' strip in each plot clipped to a 2 inch stubble height

<sup>2</sup>**Stand Index:** Estimate of plant density in 10 (1.0 sq ft) quadrats per plot. Full frame=40

<sup>3</sup>**Phenology (1983):** 1= vegetative; 2=jointing; 3=first emergence of inflorescence; 4=first anthesis, 10 culms or more;

5=50% anthesis; 6 = first seed ripe; 7 = 50% seed ripe; 8 = seed mature; 9 = complete dormancy.

\* Data is an average from these years





## Lake Andes, South Dakota

The soils are a fertile Agar silt loam. Three years of above average rainfall influenced biomass production at this site. Precipitation was above the average by 12.9 inches (1984), 10.7 inches (1986), and 3.71 (1987). Summer ranked first in average 5-year biomass production with 7,711 pounds per acre. Blackwell and Pathfinder also averaged over 7,000 pounds per acre for the 5-year period. Forestburg (34) and Pathfinder (33) had the highest stand index ratings. Pathfinder, Cave-in-Rock, and Blackwell were at 50 percent anthesis in early September. This was earlier than at the Fergus Falls site where first emergence of inflorescence was observed in early September. Phenology of the other varieties remained similar.

### Lake Andes, South Dakota (MLRA 55C, southeast SD)

**Average Annual Precipitation:** 21.37 inches

**Soils:** Agar silt loam

Variety	(pounds/acre) Biomass <sup>1</sup>							Stand Index <sup>2</sup>	Phenology <sup>3</sup>
	1984	1985	1986	1987	1988	Avg	Rank	1984	Early September
Precip. deviation	(12.9)	(-.21)	(10.7)	(3.71)	(1.0)				
Dacotah	3141 <i>c</i>	4329 <i>b</i>	3968 <i>c</i>	3585 <i>b</i>	3558 <i>d</i>	3716	8	29	8
Sunburst	5808 <i>ab</i>	6318 <i>a</i>	6319 <i>bc</i>	5969 <i>a</i>	6398 <i>abc</i>	6162	6	20	6
Forestburg	5373 <i>b</i>	6433 <i>ab</i>	6672 <i>abc</i>	5238 <i>ab</i>	5774 <i>abc</i>	5898	7	34	6
Nebraska 28	5854 <i>ab</i>	5948 <i>ab</i>	6540 <i>abc</i>	5543 <i>ab</i>	7010 <i>ab</i>	6179	5	28	7
Summer	6376 <i>ab</i>	7285 <i>a</i>	9322 <i>a</i>	7188 <i>a</i>	8386 <i>a</i>	7711	1	27	6
Pathfinder	7102 <i>a</i>	6945 <i>a</i>	8109 <i>ab</i>	6417 <i>a</i>	7602 <i>a</i>	7235	3	33	5
Cave-in-Rock	5144 <i>b</i>	7291 <i>a</i>	8764 <i>ab</i>	5147 <i>ab</i>	5044 <i>bcd</i>	6278	4	20	5
Blackwell	6664 <i>ab</i>	7411 <i>a</i>	8096 <i>ab</i>	6969 <i>a</i>	8293 <i>a</i>	7487	2	28	5

**Statistical Analyses:** Duncan's New Multiple Range Test, means with same letter are not significantly different (P=.05)

<sup>1</sup>**Biomass:** flail-type forage harvester, 2' x 10' strip in each plot clipped to a 2 inch stubble height

<sup>2</sup>**Stand Index:** Estimate of plant density in 10 (1.0 sq ft) quadrats per plot. Full frame=40

<sup>3</sup>**Phenology (1984):** 1= vegetative; 2=jointing; 3=first emergence of inflorescence; 4=first anthesis, 10 culms or more; 5=50% anthesis; 6 = first seed ripe; 7 = 50% seed ripe; 8 = seed mature; 9 = complete dormancy.



*Varietal differences at the Lake Andes, South Dakota site.*



## Onida, South Dakota

The Lowry silt loam on this site is fertile but droughty. Average annual precipitation was near normal for 3 years, considerably above normal in 1986 (5.27 inches), and below normal in 1988 (-4.07 inches). Summer, Blackwell, and Pathfinder had the highest 5-year average biomass yields of over 7,000 pounds per acre. Nebraska 28 had the highest stand index rating at 31, and Cave-in-Rock the lowest at 21. Phenology was similar to the Lake Andes site.

**Onida, South Dakota** (MLRA 53C, central SD)

**Average Annual Precipitation:** 17.47 inches

**Soils:** Lowry silt loam

Variety	(pounds/acre) Biomass <sup>1</sup>							Stand Index <sup>2</sup>	Phenology <sup>3</sup>
	1985	1986	1987	1988	1989	Avg	Rank	1984-1985*	Early September
Precip. deviation	(.13)	(5.27)	(-1.86)	(-4.07)	(.33)				
<b>Dacotah</b>	1154 <i>d</i>	5473 <i>a</i>	3533 <i>a</i>	952 <i>a</i>	1129 <i>a</i>	2448	8	27	8
<b>Sunburst</b>	3560 <i>abc</i>	7221 <i>abc</i>	4804 <i>a</i>	2814 <i>a</i>	1901 <i>a</i>	4060	3	28	7
<b>Forestburg</b>	3083 <i>bc</i>	6576 <i>bc</i>	4160 <i>a</i>	1679 <i>a</i>	1040 <i>a</i>	3308	6	28	7
<b>Nebraska 28</b>	2217 <i>cd</i>	6623 <i>bc</i>	3895 <i>a</i>	1243 <i>a</i>	404 <i>a</i>	2876	7	31	7
<b>Summer</b>	3882 <i>b</i>	9140 <i>a</i>	5122 <i>a</i>	1559 <i>a</i>	1468 <i>a</i>	4234	2	24	6
<b>Pathfinder</b>	5076 <i>a</i>	8662 <i>ab</i>	5983 <i>a</i>	2037 <i>a</i>	1994 <i>a</i>	4750	1	27	5
<b>Cave-in-Rock</b>	3053 <i>bc</i>	6794 <i>bc</i>	5106 <i>a</i>	999 <i>a</i>	1384 <i>a</i>	3467	5	21	5
<b>Blackwell</b>	4674 <i>a</i>	9266 <i>a</i>	4174 <i>a</i>	827 <i>a</i>	1319 <i>a</i>	4052	4	25	5

**Statistical Analyses:** Duncan's New Multiple Range Test, means with same letter are not significantly different (P=.05)

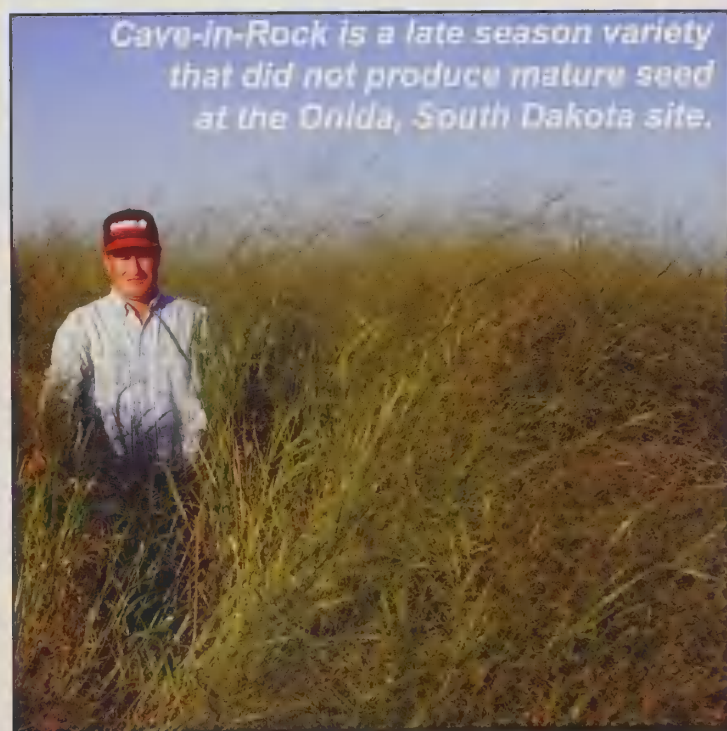
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5=50% anthesis; 6 = first seed ripe; 7 = 50% seed ripe; 8 = seed mature; 9 = complete dormancy.

\* Data is an average from these years





## Rochester, Minnesota

The soils are a well drained, rolling silt loam. This site, with 29.58 inches, had the highest annual precipitation of the six test sites. It did not, however, have the highest biomass yields. Two years were substantially above normal precipitation with increased amounts of 14.36 inches in 1990, and 7.33 inches in 1991. Three consecutive years 1987 (-2.63), 1988 (-8.19), and 1989 (-6.85) were well below normal. Summer had the highest 5-year average biomass production at 4,511 pounds per acre. Sunburst was next at 3,646 pounds per acre. Pathfinder (24), Dacotah (23), and Forestburg (23) had the highest stand index ratings. Phenology was similar to the phenology at Onida and Lake Andes sites.

**Rochester, Minnesota** (MLRA 105, southeast MN)

**Average Annual Precipitation:** 29.58 inches

**Soils:** Mount Carrol silt loam

Variety	(pounds/acre) Biomass <sup>1</sup>							Stand Index <sup>2</sup>	Phenology <sup>3</sup>
	1987	1988	1989	1990	1991	Avg	Rank	1985-1987*	Early September
Precip. deviation	(-2.63)	(-8.19)	(-6.85)	(14.36)	(7.33)				
Dacotah	2133 c	1898 a	995 b	1636 c	1227 c	1578	10	23	8
Sunburst	4323 abc	3063 a	3175 a	3672 ab	3995 ab	3646	2	15	6
Forestburg	2598 bc	1791 a	1158 b	2330 bc	1670 c	1909	8	23	6
Nebraska 28	2716 bc	1752 a	1127 b	1756 bc	1825 c	1835	9	17	6
Summer	4663 ab	4647 a	3849 a	4931 a	4465 a	4511	1	14	5
Pathfinder	3724 abc	2170 a	1221 b	2068 bc	2079 c	2252	7	24	4
Trailblazer	3429 abc	2596 a	1453 b	2061 bc	1928 c	2293	6	12	5
Cave-in-Rock	5253 a	3743 a	3159 a	2487 bc	2842 ab	3496	3	18	5
Blackwell	5528 a	2812 a	2370 ab	2699 bc	2680 bc	3218	4	21	5
NJ-50	3841 abc	2264 a	2347 ab	1268 c	1823 c	2309	5	9	4

**Statistical Analyses:** Duncan's New Multiple Range Test, means with same letter are not significantly different (P=.05)

<sup>1</sup>**Biomass:** flail-type forage harvester, 2' x 10' strip in each plot clipped to a 2 inch stubble height

<sup>2</sup>**Stand Index:** Estimate of plant density in 10 (1.0 sq ft) quadrats per plot. Full frame=40

<sup>3</sup>**Phenology (1990):** 1= vegetative; 2=jointing; 3=first emergence of inflorescence; 4=first anthesis, 10 culms or more;

5=50% anthesis; 6 = first seed ripe; 7 = 50% seed ripe; 8 = seed mature; 9 = complete dormancy.

\* Data is an average from these years





## Fort Pierre, South Dakota

Promise clay is fertile with low permeability. Infiltration is less than 0.2 inches per hour. Three consecutive years (1988, 1989, 1990) of significantly lower than normal rainfall greatly reduced the 5-year average biomass yields. Blackwell, Summer, and Pathfinder were the only varieties with average forage yields over 3,000 pounds per acre. Summer, Trailblazer, Pathfinder, Sunburst, and Nebraska 28 produced the most biomass during the two years with near normal rainfall (1991, 1992). Production ranged from 5,000 to 6,000 pounds per acre. Forestburg and Nebraska 28 had the highest stand index ratings (26) and Cave-in-Rock had the lowest (12). Phenology was recorded during the two driest years (1988, 1990). Earlier varieties, such as Dacotah and Forestburg, had similar phenology to the other sites. The later varieties had delayed maturity.

### Fort Pierre, South Dakota (MLRA 63A, central SD)

**Average Annual Precipitation:** 18.08 inches

**Soils:** Promise clay

Variety	(pounds/acre) Biomass <sup>1</sup>							Stand Index <sup>2</sup>	Phenology <sup>3</sup>
	1988	1989	1990	1991	1992	Avg	Rank	1986-1987*	Early September
Precip. Deviation	(-7.3)	(-4.77)	(-5.74)	(.87)	(.79)				
Dacotah	1060 <i>b</i>	209 <i>c</i>	2061 <i>bc</i>	4575 <i>ab</i>	2282 <i>d</i>	2037	9	24	8
Sunburst	1568 <i>a</i>	578 <i>ab</i>	3170 <i>abc</i>	5320 <i>a</i>	3179 <i>cd</i>	2763	5	22	5
Forestburg	869 <i>b</i>	273 <i>bc</i>	2752 <i>abc</i>	4884 <i>ab</i>	4124 <i>bc</i>	2580	7	26	6
Nebraska 28	1018 <i>b</i>	384 <i>bc</i>	1404 <i>c</i>	4900 <i>ab</i>	3821 <i>c</i>	2305	8	26	5
Summer	2390 <i>a</i>	837 <i>a</i>	2838 <i>abc</i>	4027 <i>bc</i>	6102 <i>a</i>	3239	2	14	5
Pathfinder	1863 <i>a</i>	498 <i>abc</i>	3578 <i>ab</i>	4931 <i>ab</i>	5186 <i>ab</i>	3211	3	20	3
Trailblazer	1423 <i>a</i>	473 <i>bc</i>	2055 <i>bc</i>	4293 <i>ab</i>	6023 <i>a</i>	2853	4	21	3
Cave-in-Rock	1743 <i>a</i>	627 <i>ab</i>	2009 <i>bc</i>	3098 <i>c</i>	5751 <i>a</i>	2646	6	12	4
Blackwell	1342 <i>a</i>	608 <i>ab</i>	4096 <i>a</i>	4496 <i>ab</i>	5809 <i>a</i>	3270	1	23	3

**Statistical Analyses:** Duncan's New Multiple Range Test, means with same letter are not significantly different (P=.05)

<sup>1</sup>**Biomass:** flail-type forage harvester, 2' x 10' strip in each plot clipped to a 2 inch stubble height

<sup>2</sup>**Stand Index:** Estimate of plant density in 10 (1.0 sq ft) quadrats per plot. Full frame=40

<sup>3</sup>**Phenology (1988,1990):** 1= vegetative; 2=jointing; 3=first emergence of inflorescence; 4=first anthesis, 10 culms or more;

5=50% anthesis; 6 = first seed ripe; 7 = 50% seed ripe; 8 = seed mature; 9 = complete dormancy.

\* Data is an average from these years





## Key Establishment and Management Considerations

- **Soils/Adaptation:** Plant performance is best on moderate to fine textured deep soils in areas of greater than 14 inches of average annual precipitation. Western and northern varieties are generally adapted to drier conditions.
- **Seeding:** Switchgrass is a small, smooth seed with approximately 390,000 seeds per pound. The NRCS recommended drilled seeding rate for North Dakota is 4.5 pounds per acre in the eastern part of the state, and 3.5 pounds in the west. Rates are calculated on Pure Live Seed (PLS). The recommended broadcast seeding rate is two times the recommended drill rates. Seeding rates vary across the United States, generally increasing from west to east. The recommended seeding rate is 10 PLS pounds per acre in the southeastern United States (USDA, NRCS 2006b). Spring or fall dormant seeding dates are recommended. A firm seedbed is essential for a shallow seeding depth (1/4 inch). Studies have shown an average germination of 65 percent when planted 1 inch deep, and zero germination when planted 2 inches deep (USDA, NRCS 2003).
- **Weed Control:** Abundant broadleaf weeds and annual grasses need to be controlled by mowing and/or herbicide application. Young plants of annual foxtails (*Setaria* species) look very similar to switchgrass seedlings. Dense stands of foxtail can be very competitive and significantly reduce stand establishment. Herbicides generally are more effective than mowing in controlling annual grasses.
- **Grazing/Haying:** Palatability and digestibility of switchgrass are good when harvested in the early boot stage. Allow for 8 inches of stubble in early summer and 12 inches in late summer (USDA, NRCS 2006b).





- **Mowing:** Switchgrass has an elevated growing point. A mowing height of less than 6 inches in late spring or early summer may reduce stand density. Boe (2005) recommends delaying harvest until late summer or early fall for stand longevity and stable long-term biomass production.
- **Phytotoxicity:** Switchgrass is reported to be toxic to horses, sheep, and goats when grazing pure stands. The toxicity can cause photosensitivity and affect internal organs and liver function (USDA, NRCS 2002). No problems have been noted for cattle.
- **Fertilization:** Biomass quality and yield, and seed production can be improved with nitrogen application. A soil test is recommended to achieve maximum productivity.
- **Burning:** Switchgrass benefits from burning of plant residues prior to initiation of spring growth. Advantages include low impact residue removal; weed control; more uniform growth initiation and seed ripening; improved nutrient recycling; and more vigorous growth. Burning annually at the Bismarck PMC has increased long-term seed yields.
- **Seed Harvest:** Seed shattering may occur shortly after the first seed is ripe. Conventional grain harvesting equipment can be used with proper setting adjustments. Seed is subject to heating. Fields should be as weed free as possible prior to harvest. Many weed seeds (especially foxtails) are similar in size and shape to switchgrass and can be difficult to remove during the cleaning process.



*A prescribed burn is an important management tool.*





***Switchgrass varieties differ in size and phenology. This PMC demonstration planting at Mandan, North Dakota, includes from left to right, Dacotah, Forestburg, Nebraska 28, ND-3743, Sunburst, Summer, and Pathfinder.***

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